DOCUMENT RESUME

ED 144 255 EA 009 973

AUTHOR	Schulz, Joan
TITLE	Lighting and the Learning Space. OSSC Bulletin Vol. 21, No. 2.
INSTITUTION	Oregon School Study Council, Eugene.
PUB DATE	Oct 77
NOTE	43p.; Some parts may be marginally legible due to type size
AVAILABLE FROM	Oregon School Study Council, 124 College of Education, University of Oregon, Eugene, Oregon 97403 ($2.00; $1.50 if prepaid; 10% discount for 10 or more copies)
EDRS PRICE	MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS	*Classroom Environment; Color; Elementary Secondary Education; Flexible Lighting Design; Glare; *Illumination Levels; Learning; *Lighting; Lighting Design; Measurement Techniques; Physical Design Needs; Readability; School Planning; Standards; Teacher Responsibility; Visual Acuity; *Visual Environment

ABSTRACT

Poor lighting conditions in classrooms result not only from low intensity light but also from too high intensity light, an uneven distribution of light, and glare. Since visual tasks in a classroom constitute 62 percent of a student's time in school, suggestions are made of ways lighting conditions can be improved. The principles and characteristics of different types of illumination--incandescent, fluorescent, mercury vapor lights, and metal halide lamps--are explained. Techniques for the measurement of illumination, brightness or intensity, reflection and glare, and light distribution are outlined. A brief explanation is given of print types, line widths, leading, colored inks, and colored papers as they relate to the speed of reading. (Author/MLF)

****
* Documents acquired by ERIC include many informal unpublished *
* materials not available from other sources. ERIC makes every effort *
* to obtain the best copy available. Nevertheless, items of marginal *
* reproducibility are often encountered and this affects the quality *
* of the microfiche and hardcopy reproductions ERIC makes available *
* via the ERIC Document Reproduction Service (EDRS). EDRS is not *
* responsible for the quality of the original document. Reproductions *
* supplied by EDRS are the best that can be made from the original. *
****

OSSC BULLETIN

LIGHTING AND THE LEARNING SPACE

by

Joan Schulz

Individual copy--$2.00 ($1.50 if prepaid)
Discount of 10% for 10 or more copies

FOREWORD

With little new school construction due to enrollment growth today, it is possible for school districts to focus more attention on the quality of existing learning environments. In this Bulletin, Joan Schulz points out the effects of poor lighting conditions in classrooms. Pupil eye strain may result not only from low intensity light but also from too high intensity light, an uneven distribution of light, and glare. Reflections of light have been shown to reduce the speed and accuracy of pupil word recognition. In fact, efforts to increase the intensity of lighting to help pupils see better can make a bad situation worse as shadows become more pronounced and glare more uncomfortable.

Visual tasks in a classroom constitute 62 percent of a pupil's time in school. This is complicated by the fact that a typical school today will find 20 percent of the children enrolled with below normal vision. Therefore, it is timely for school board members, superintendents, principals, and teachers to review Joan Schulz's article and its suggestions as to how they may ease the reading tasks of pupils in the classrooms.

Special appreciation is expressed to Dr. Mildred Robeck, under whose sponsorship this Bulletin was prepared.

Kenneth A. Erickson
Executive Secretary
Oregon School Study Council

TABLE OF CONTENTS

	Page
Introduction	1
Aspects of Lighting	7
Measurement of Illumination	10
Brightness or Intensity of Light	13
Reflection and Glare	15
Distribution of Light	17
Flexibility and Control	18
Light and the Printed Page	19
The Teacher's Responsibility	27
Notes	32
Selected Bibliography	35

LIGHTING AND THE LEARNING SPACE

"Students experience better physical growth and fewer visual difficulties in properly decorated teaching spaces."

Dr. John W. Gilliland

Introduction

Since, as Sommer writes in Design Awareness, " . . . the onus of the argument for a decent environment always falls upon the person who wants to improve things . . . "--the designer with a desire to improve the teaching space must know the beneficial and detrimental aspects of such basic physical elements as thermal and acoustical environment, flooring, wall and ceiling surfaces, color, and lighting. The illumination of the classroom is particularly important for it has a major impact on the physical environment both aesthetically and psychologically. This impact is of great importance to the pupils and the teacher, for it is a major influence on their mental and physical well-being, and on the learning process.

The major portion of information acquired by the individual comes to him through the eyes and the ears. However, we are generally oblivious to the quality and quantity of light in which we work since the human eye is capable of adjusting to a broad range of conditions.

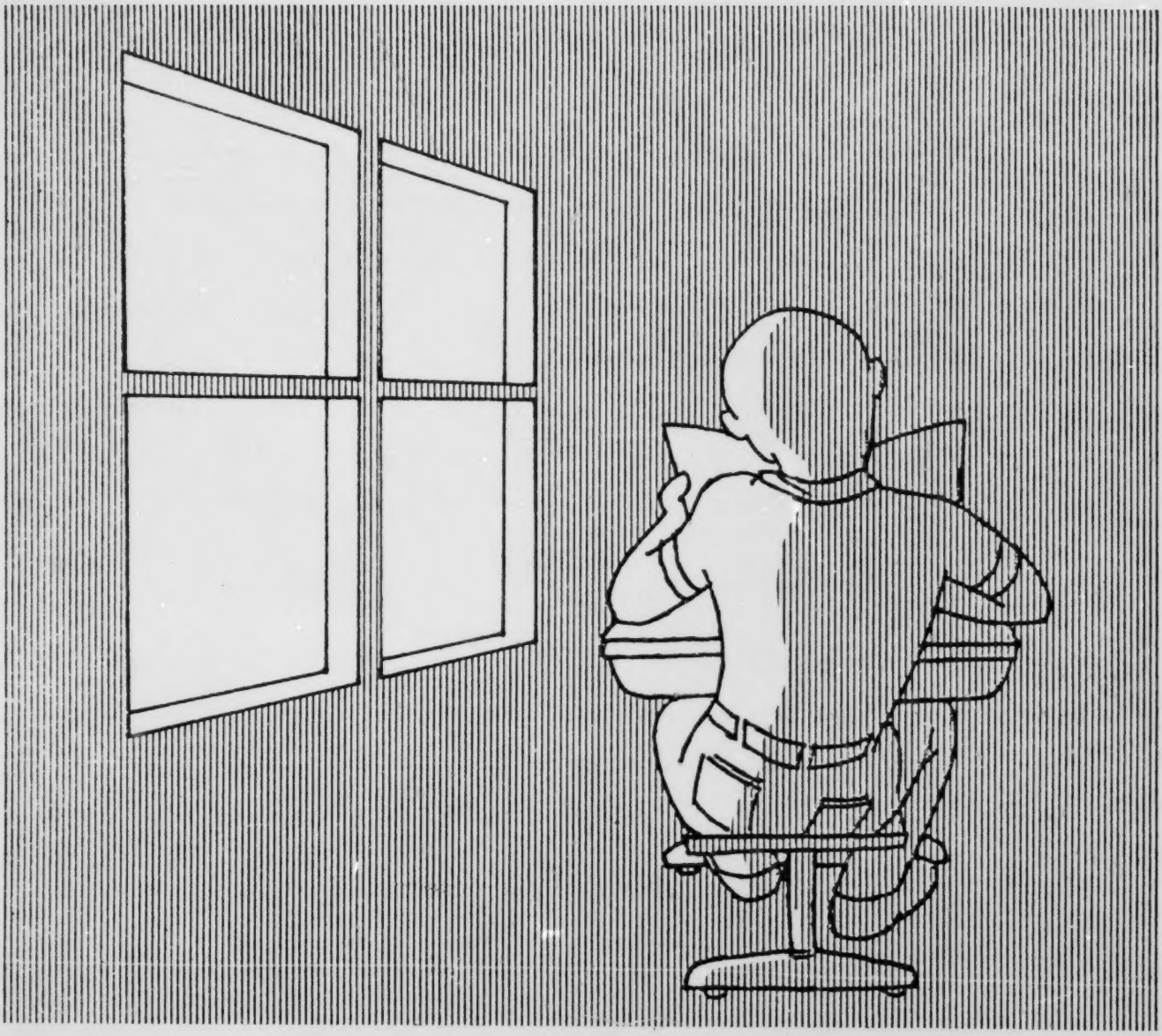
> The human eye, a one-inch ball, is remarkable in its own right. With it we can detect the difference among some million colors. We can detect the flare of a match ten miles away on a clear night. And we can detect the presence of a

> wire, 1/16 inch in diameter, at a distance of half a mile. The latter measure amounts to the detection of an object less than half the size of the retinal cells used to detect it.[1]

Consider also that one can read a newspaper in brilliant sunlight and, with average vision, read that same paper by the full moon.

However, without light the human eye does not function. The question is how much and what type of lighting is most advantageous for the highest degree of proficiency without fatigue and strain, since learning involves predominantly the reading of printed material. About 64 percent of the visual task time is concentrated on reading, writing, and using duplicated materials.[2] Visual tasks also include adjustment from reading and writing at the desk, to reading charts, maps, and the chalkboard, or seeing movies, TV, slides, and material on the overhead projector, all at a distance. The students' eyes are making constant adjustments.

Poor lighting, which includes glare, uneven distribution, and too low or too high an intensity, forces the eyes to strain in an attempt to see better. The student may bring an object nearer his face or bend closer to the desk surface in an attempt to see more clearly. This causes a contraction of the eyeball muscles and of the tiny muscles which control the size of the pupil and the shape of the lens. The resulting eye fatigue slows the reading and comprehension ability. Without realization of the cause, the students attempt to adjust to the discomfort of faulty lighting by twisting their bodies in some way to shield their eyes, which can result in inefficient physiological functioning, image distortion, wasted energy, and damaging stress to either



A CHILD WILL AUTOMATICALLY ADAPT TO AN ADVERSE LIGHTING CONDITION BY ADJUSTING HIS SEATING POSTURE, THEREBY SETTING UP STRESSES IN BOTH HIS VISUAL AND SKELETAL SYSTEMS. 3

(Illustration from Environment for Learning)

the eyes or the body or both.[3] Physical signs which may point to eye and lighting problems include nervousness, irritability, headaches, dizziness, shorter attention spans, loss of appetite, nausea, and other stomach symptoms. Mental fatigue often results from physical conditions the body is attempting to overcome.

Damage to the eyes themselves can result from inadequate illumination. For example:

> An established ophthalmological principle states that a difference in intensity of illumination between the two eyes amounting to over 12 percent leads to a suspension of vision in one eye which may very well be followed by injuries to that eye.[4]

Studies have shown several advantages, physically and educationally, of quality classroom light:

1. Greater comfort and contentment.
2. A more cheerful environment which is more conducive to mental health.
3. More concentration and a greater desire to work.
4. Less fatigue and therefore fewer side effects such as laziness, bad posture, nervousness, and lack of interest.
5. Greater accuracy and neatness.

Light influences our work performance, our general comfort, our dispositions, our attitudes toward the things and the people we encounter daily.[5]

The learning process uses a great deal of "seeing energy." Research at the Mayo Clinic (projects at the University of Michigan and Tufts College) concluded that about "25 percent of the individual's energy was expended in just seeing under good to normal conditions,

with poor visual conditions increasing the percentage."[6] Energy losses can be measured by blink rates, ocular convergence, and muscular tension.

With inefficient and insufficient lighting in the learning space, it is speculated that young children just beginning school could fall into a pattern of poor learning habits due to fatigue, discomfort, and mental and physical stress. These habits and the resulting attitudes influence the remainder of the formal education and the lifelong potential of the child.[7]

According to the National Society for the Prevention of Blindness:

> . . . visual efficiency has a marked effect upon many learning situations and it is influenced by a number of factors: (1) the stage of growth and development of the child's eyes, (2) the presence of eye defects, (3) relative brightness of object and background [contrast], (4) size of object, (5) distance of the object, (6) amount of illumination, and (7) glare. . . . (1) quantity of illumination, (2) quality of illumination and brightness balance, (3) reflection factors in the environment, (4) natural lighting and its control, (5) artificial lighting and its control, and (6) maintenance.[8]

In Health and Light (1973) several cases of the effects of wave lengths of light are revealed. The employees of a Florida radio station replaced the regular white fluorescent tubes with deep pink tubes in an attempt to brighten up their working environment. In two months the employees grew irritable, began performing less efficiently, a few resigned, others disagreed constantly with management decisions. Then, one day an employee exclaimed, "If those pink bulbs aren't removed, I'll go out of my mind." With the return of the white fluorescent tubes, tempers cooled and irritability decreased noticeably within a week. Another example is that of a Kansas City Royals baseball player who

wore pink-tinted glasses constantly and was a "hyper-aggressive and helmet-throwing player." With his glasses changed to medium gray, he changed "to a very relaxed, confident person."[9]

C. L. Crouch, Director of Research for the Illuminating Engineer Research Institute in New York City writes:

> I believe that one of these days we will be prescribing illumination not only on the basis of visual performance, but also on the basis of the health and welfare of people. While we have been primarily concerned with the effect of light on human vision, there has been a growing body of information about the effect of wave-lengths of light on the health and welfare of human beings.[10]

Research in this area may result in beneficial lighting developments for schools. The Environmental Health and Light Institute experimented with windowless first-grade classrooms in Sarasota, Florida--using a new full-spectrum light called Vita-Lite. Marked behavior changes were noted in hyperactive children. They became calmer and more interested in their school work. The control rooms used standard cool-white fluorescent tubes and fixtures.[11]

Another experiment at Cornell University involved students studying for four hours a day, for four consecutive days. Two days the students studied under Vita-Lite and two days under standard cool-white fluorescent light.

> . . . the effect of the sunlight-simulating source (Vita-Lite) was actually to enhance visual acuity over time rather than merely to minimize fatigue. This may have been due simply to adaptation . . . If so, the results suggest that it was easier to adapt to Vita-Lite . . . [12]

Further research in the area of human behavior and the visual environment should be interesting.

Teachers and students should have a lighted environment conducive to ease in the seeing tasks. There can be no argument against the reduction of discomfort and fatigue. Along with this we should include safety, beauty, comfort, and full utilization of space.

> Classroom lighting design plays a particularly critical educational role because of the direct relationship between good lighting and a student's performance, between eye fatigue and eye health, and between eye health and general health. Both performance and health mark the adult for life since no one yet has managed to go back and re-do his early years.[13]

Aspects of Lighting

According to most sources no common type of illumination has yet been proven better than any other for tasks such as reading and writing. Recommendations for schools usually specify fluorescent lights, or a combination of fluorescent and incandescent. Although a variation in color is now available, most people "feel better" in the rosier, flattering lights than under the cold-blue tones.[14]

Incandescent lights provide the warmer color of light, emitting more yellow than the fluorescent or mercury vapor lights. Incandescent lights are evacuated envelopes of glass filled with an inert gas which reduces evaporation of the filaments. The filaments, usually an alloy of tungsten, provide illumination when heated to incandescence. More help for school lighting problems may be found in the newer tungsten halogen (quartz-iodine) lamp types.[15]

Incandescent bulbs are available in general purpose types used in fixtures and lamps for general illumination, as well as in reflector

bulbs for accent lighting and colored bulbs for spatial effects.

Since an incandescent bulb is a concentrated source of light, it is useful for spotlighting particular areas such as art work, charts, displays, and plantings. It would also be appropriate for cozy reading areas. However, the bulbs are more apt to produce glare and are more costly to operate, with a shorter life and lower light output than fluorescent tubes.[16] There is the advantage of being able to use different wattages in the same socket with the incandescent fixtures.

Fluorescent lights are less expensive to operate and maintain than incandescent lights and therefore find many uses in public areas. The tubes are usually straight, but curved and U-shapes are available. The cost of installing fluorescent fixtures is more than the installation of incandescent, but maintenance and operation is less expensive, especially for high levels of illumination in offices, industry, and public buildings. Long fluorescent fixtures with diffusers produce less glare and fewer shadows than incandescent fixtures do in the same area.[17]

Fluorescent tubes are glass tubes filled with mercury vapor. They have a fluorescent interior coating which makes them absorb the short-wave radiation and emit a spectrum of longer wave lengths. The distribution of the light can be changed by using different coating materials.

> Fluorescent tubes are available in a range of shades that can be used to provide a cool or warm atmosphere and supply the right color tone for fabric, merchandise, or wall color. Natural White is generally preferred for store applications. It provides more red than most fluorescent and flatters complexions. Warm White creates a warm atmosphere and is close in color to the light of an incandescent bulb. It makes red and yellows warm and bright, brings out the yellow in green, adds a warm tone to blue. Its light appears yellower at lower levels of illumination. Deluxe Warm White

> has a beige cast that is warmer than Warm White, brightens reds and yellows, and darkens blues and greens. It blends well with incandescent light. Cool White produces a cool, neutral light with a blue-gray cast. Deluxe Cool White is similar, but has a red element added that improves the appearance of reds. It has little distortion but tends to gray colors slightly. White has a yellowish cast and accentuates yellows, yellow-greens, and orange. It strengthens tans, pinks, and greens, but will gray blues. Soft White has a pink cast and clarifies and brightens some pinks, reds, and tans. It is somewhat flattering to the complexion but dulls yellows and grays greens. Daylight has a blue cast similar to north light or natural daylight. It makes blues and greens bright and clear, and tends to gray reds, yellow, and orange. It is not flattering to the complexion.[18]

Colored fluorescents--blue, green, yellow, gold, pink, and rose--are useful for dramatic display effects.

> Up to 1970, no existing fixture, by means of reflector or lens, controlled the resulting veiling reflections to the degree now recommended in the new classroom standards. . . . Since all IES standards have always been a compromise between the ideal and the possible, IES had never before been able to recommend the degree of indirect glare control required for good seeing conditions.[19]

With the development of the "twin beam" fluorescent fixture, the light rays are directed out the sides and along a narrow axis in twin beam patterns, with a minimum of light directed down. Sufficient fill light, however, is provided to meet all general standards.[20]

Mercury vapor lights are similar to fluorescent in that the white light emitted can vary in hue. Mercury vapor lights last a little longer than fluorescent and are slightly more expensive to buy. However, it takes more fluorescent lights to create a stated light level. The depreciation rate in quantity of light given off is greater than in fluorescents.[21] The new metal halide lamp combines the best qualities of the mercury vapor light with a better color characteristic, more light per watt, and more usage indoors and out.[22]

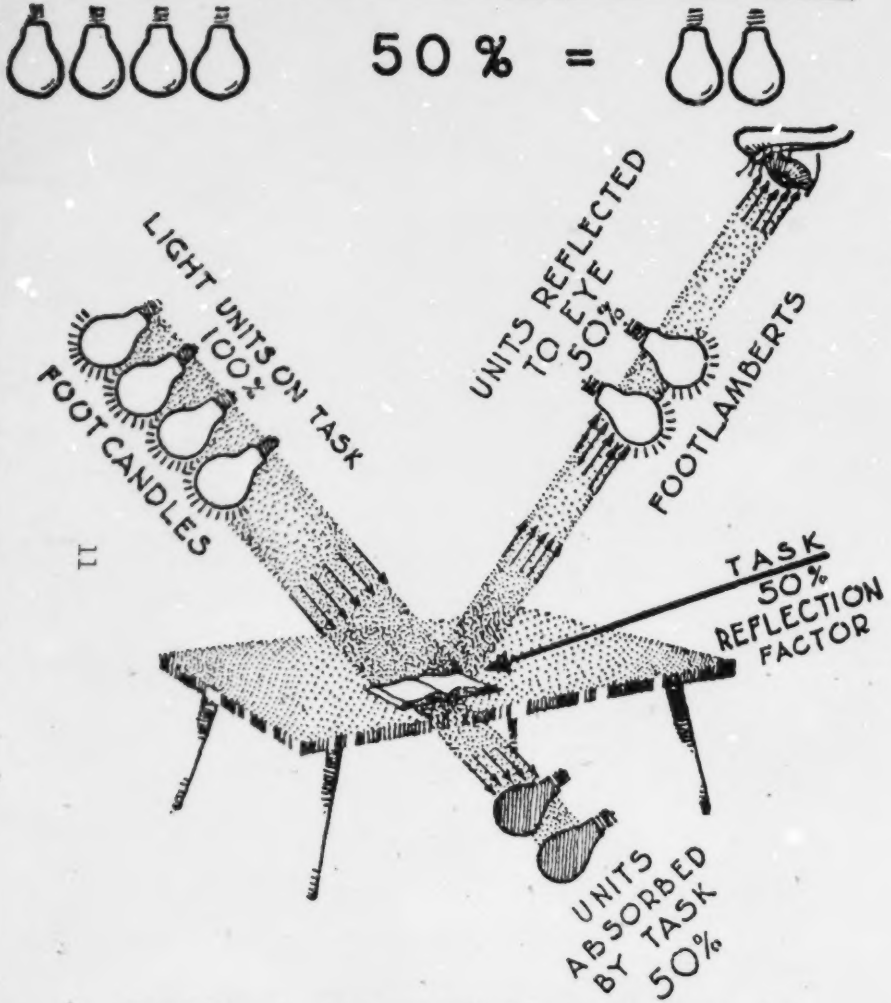
One disadvantage of the mercury vapor light is the necessity for it to cool before relighting. This requires the use of small quartz lamps for illumination during this cooling period before the mercury arc lights will operate again.[23] Mercury vapor lights have been used for gymnasiums, music centers, activity courts, and resource centers, as well as large open plan teaching spaces.

No type of artificial lighting is superior to natural well-diffused daylight. The human eye responds more favorably to daylight in speed of vision, accuracy, and sustained acuity.[24] In choosing artificial lighting, therefore, consideration should be given to a light that produces full-spectrum illumination like that of natural light. Vita-Lite is a fluorescent light said to closely approximate the spectral quality of natural sunlight, and has been used with some interesting results in experiments with plants, animals, and people.[25]

Measurement of Illumination

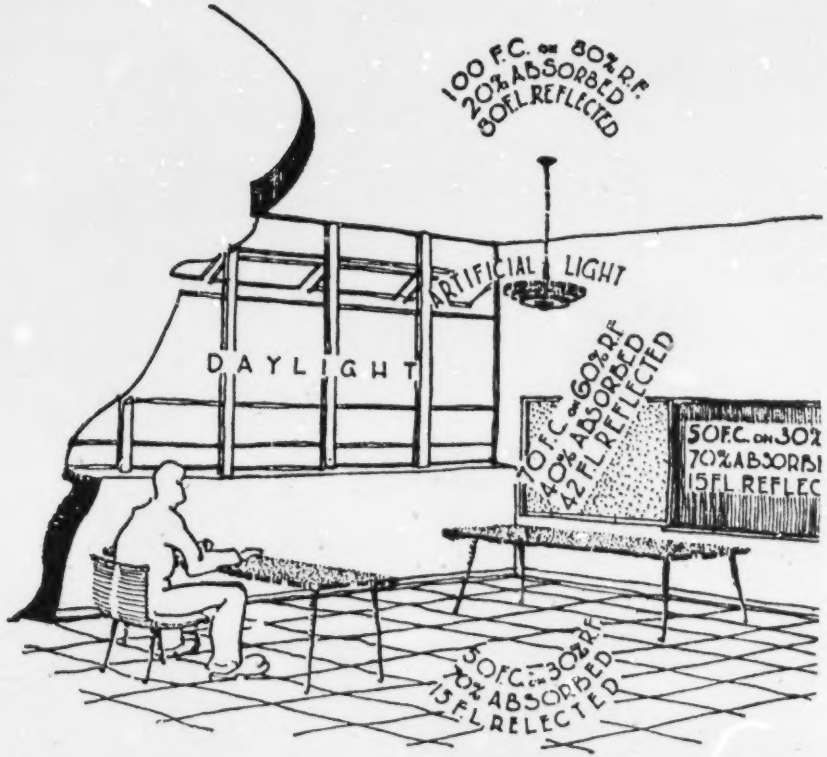
The foot-candle, a standard measurement for the source of light, refers to the amount of light falling on a square inch of surface one foot from a standard candle. This light can be measured by a foot-candle meter in fractions or number of foot-candles. The foot-lambert is used to measure the brightness of other surfaces. "Foot-lambert" is the result of the illumination in foot-candles and the reflection factor of the surface. This is the light by which we actually see and is therefore the most important factor in the visual comfort of an environment.

FC x RF = FL



The light unit which activates the visual process is the foot-lambert. The task indicated above becomes visible because of reflected brightness. This brightness is the product of the foot-candle intensity and the reflection factor of the task. The foot-lambert, then, rather than the foot-candle, becomes the prime factor in conditioning an environment for visual comfort and efficiency because it is the reflected brightness that we see and not the light falling upon the task.

FC (FOOT-CANDLES) x RF (REFLECTION FACTOR) = FL (FOOT-LAMBERTS)



The reflection factor of ceilings, walls, chalkboards, floors, and equipment determines to a large extent the degree of brightness-balance that can be attained in a classroom. The efficient utilization of light energy, whether from daylight or artificial sources, is dependent upon the reflection factor of the surface upon which it falls.

(Illustration from Guide for Planning School Plants)

The measurement of foot-candles or foot-lamberts does not guarantee, however, that the lighting is sufficient. The luminaire efficiency is measured in Equivalent Sphere Illuminance (ESI), which is the measure of glare-free illumination. ESI can be evaluated with a field task photometer.

Everyone would prefer to have adequate light for the task being performed. Visibility increases rapidly from darkness to 50 foot-candles, after which the amount of light must be doubled and redoubled to noticeably increase visual efficiency for a specific task. According to Faber Birren in Color for Interiors--Historic and Modern (p. 136), rather than increase the general level of illumination much above 50 foot-candles, which is considered optimum, task lighting should be considered. For average-sized print on paper providing good contrast, 20 to 30 foot-candles has been considered satisfactory.[26] However, with the multitude of tasks, the poor contrast of some materials, children's eye problems, as well as the variety of ages which may use the teaching space, an intensity of 50 to 60 foot-candles of glare-free illumination is recommended.[27]

In any lighting system, consideration should be given to the depreciation of lamps, luminaires, and to the painted surfaces when planning the quantity of light.

Reflection and glare are important factors in the illumination of an environment, along with the intensity of the light, its distribution and the flexibility of the lighting system.

Brightness or Intensity of Light

Brightness is the amount of light from a light source, its distribution, and the amount of light reflected from the surfaces surrounding the light.

The human eye adapts to the light level of the task at hand, the adaptation being a combination of task brightness and field brightness. As the eyes shift from one viewing task to another, a book on the desk to writing on the chalkboard, the eye again adapts to the task and field brightness. If the change in brightness is nominal, the adaptation is also nominal; however, should the change in brightness be great, the adaptation requires more time and energy and can, in extreme cases, cause discomfort to the viewer. For visual efficiency the brightness of the task should equal or be slightly more than the surrounding or field brightness.[28]

Having a direct bearing on the brightness levels and distribution of light is the way the light is directed and how it is reflected. Pendant luminaires and suspended direct-indirect fixtures project the major portion of the light up toward the ceiling, thus there is little brightness difference between the fixtures and the ceiling if the spacing is adequate and allows even light distribution. Insufficient spacing from fixture to ceiling causes excessive brightness directly above the fixture and low brightness between the luminaires. Surface mounted luminaires should be spaced to provide an even light distribution between the fixtures, otherwise dark and light bands will result. Recessed units may also result in too much contrast between luminaire and

adjacent ceiling areas. With the light projected directly down from recessed units, the reflection factors of the walls, floors, and other surfaces is of vital importance. Dark surfaces with low reflection can result in inadequate lighting, thus causing fatigue in the visual field. Another factor to be considered with surface-mounted and recessed luminaires is the width of the unit. Narrow units tend to be brighter, causing greater differences between the fixture and the field brightness of the ceiling itself.

Although a balance of brightness is necessary, it is also desirable to have some variety in the environment. The magazine article, "Brightness Patterns Improve Classroom Attention," (American School and University, August, 1974, p. 32) reveals that the attention of students in the classroom is significantly increased when using spotlights on charts, thus "reinforcing brightness patterns."

Recommended guidelines for brightness balance from the 1976 Guide for Planning Educational Facilities are:

(1) No large areas should have a brightness less than one-third the task brightness.

(2) No area adjacent to the task should be brighter than three times the brightness of the task.

(3) No area in the visual environment should be brighter than five times the brightness of the task.[29]

The final choice of size, type, and number of lamps per luminaire will be dependent upon the desired level of illumination, the module size selected for space division, the brightness characteristics of the luminaire, and the efficiency of the total installation.[30]

Reflection and Glare

The reflection of light from surfaces in an interior space is an important element of the visual environment. The efficient utilization of the illumination is determined by surfaces of the walls, ceiling, floor, and furnishings. These reflections of light vary from the shine of a mirror-like surface to the totally diffuse reflection of the flannel board. This "reflectivity" can be expressed in a percentage of the incident light reflected in any way from the surface. Light colors and high gloss surfaces have higher reflection than dark colors and rough textures. Therefore, careful attention should be given to wall and ceiling colors, colors of tack and chalk surfaces, furnishings, and flooring when the types and amounts of illumination are planned. For example, a recessed luminaire depends on floor reflection that is higher than other types of lighting. Dark carpeting, reflecting little light, will cause the ceiling to look darker than it is--a poor combination for the teaching area.

Desk and table tops are significant reflective surfaces in the classroom. These should have 35 to 50 percent reflection with a matte or dull gloss finish.[31] Older dark furnishings can be sanded to expose the natural wood, and when given a lacquer or matte varnish finish, they resemble light-finished maple or birch. The dark-painted or varnished surface provides too much contrast with light-colored papers and book pages.

Fixtures directing light downward can cause a loss of visibility referred to as veiling reflections. The light strikes the task and

bounces into the eyes at the normal viewing angle, which is centered around the 25-degree zone or the "offending zone."[32] These veiling reflections reduce the speed and accuracy of word recognition. Reducing the amount of light projected down and increasing light from the ceiling and the walls results in a more uniform distribution of light for the task at hand. Large areas of lower brightness are more beneficial than small areas of higher brightness. Wall brightness is of particular importance for the light to be evenly distributed. Direct light reflected from the ceiling alone is the main cause of veiling reflections. Veiling reflections may be corrected by redirecting or rearranging the light source and/or its distribution.

Glare is brightness which causes discomfort, poor visibility, and distraction. If the glare is associated with the source of light and the immediate surroundings, it is "direct glare." If it is associated with the task and its surroundings, it is "reflected glare." Direct glare may come from windows, particularly small windows in a darker wall area, and from light fixtures, those with exposed bulbs or darker surrounding surfaces. Reflected glare is that received from glossy paper, metal surfaces, shiny plastic covers, chrome trim, etc. The angle of the reading material is an important factor when considering reflected glare. Try placing a mirror on your reading material. If it reflects any of the light source, the reading material is not placed properly and reflected glare is interfering with visual comfort.[33]

IES (Illuminating Engineering Society) standards have now been revised concerning indirect glare control required for good seeing

conditions. This has been made possible by the development of the "twin-beam" fluorescent fixture.[34]

Distribution of Light

The light distribution throughout the teaching area should be even, without glare and shadowed areas. Increasing the intensity of lighting to "see" better can make a bad situation worse; the shadows can, in fact, become more pronounced and the glare more uncomfortable.

Dr. Foster K. Sampson, a consulting lighting engineer, directed a West Coast research project in which the lighting of eighteen classrooms was checked to "determine how the contrasts in lights from different sources affect the ability to see visual tasks."[35] Educational Facilities Laboratory has published a complete description of the project entitled Contrast Rendition in School Lighting.[36] Although no single lighting system was determined as better than all others, there are some factors which may help in selecting school lighting. There are three benefits reported for lighting systems around the periphery:

(1) The level of illumination is much more uniform.

(2) The side wall and chalkboard lighting was better.

(3) The increase of light reflected from the sides of the room make a marked increase in the visibility of pencil handwriting.[37]

Projects which ranked first and second of eighteen had periphery lighting; the project ranking third utilized four bays, each about 11' square with coves in the four sides lighting a 28" deep coffer.

Flexibility and Control

Flexibility of the illumination in the teaching area is necessary to accommodate a variety of programs, including the community school in which people of all ages will utilize the space. With open-plan schools, lighting must facilitate a fluid program with different activities in adjacent areas. The designer, in considering a lighting system to serve programs and people, must give thoughtful consideration to adequate switch planning, the number and configuration of fixtures. Circuits must be arranged to facilitate dimming in one area for an overhead projector, reading in another area, and discussion groups, a movie, or a play within the same open space. Lights in long strips would not be feasible in an open plan situation. Square or rectangular groupings of fixtures on separate switches with rheostats would be desirable.[38] The self-contained classroom also needs lighting with a range of capabilities. "We have found that by using the approach to lighting which is responsive to actual needs, both first costs as well as operating costs can be reduced."[39]

Thought should also be given to auxiliary lights for highlighting maps, chalkboards, display areas, or children performing for classmates. Different types and combinations of lighting help to prevent monotony and flatness inherent in quantities of generally distributed fluorescent illumination.[40]

Another source of light, daylight, needs to be controlled to reduce glare, provide for use of visual aids, etc. Popular methods are window shades, drapery, venetian blinds, wide exterior overhangs,

outdoor vertical and horizontal louvers, or inside or outside shutters. Automatic controls which adjust the louvers according to the natural lighting intensities have been utilized, along with automatic switching for artificial illumination--in accordance with natural lighting from the windows. Window shades should be the type that may be adjusted up or down from the middle, for often glare can be controlled with use of the bottom shade while light from the top of the window distributes itself over upper walls and ceiling--providing good illumination. The window treatments should be light in color to prevent excessive contrast with adjacent wall surfaces.

Light and the Printed Page

Visual tasks constitute 62 percent of the student's time. Of this percentage, 64 percent is spent using duplicated materials, writing with a pencil, and reading, therefore the quality of the printed material should be carefully considered.[41] A brief explanation of print types, line widths, leading, colored inks, and colored papers as they relate to the speed of reading is beneficial:

> Legibility of print is concerned with perceiving letters and words, and with the reading of continuous textual material. The shapes of letters must be discriminated, the characteristic word forms perceived, and continuous text read accurately, rapidly, easily, and with understanding. In the final analysis, one wants to know what typographical factors foster ease and speed of reading.
>
> Optimal legibility of print, therefore, is achieved by a typographical arrangement in which shapes of letters and other symbols, characteristic word forms, and all other typographical factors such as type size, line width, leading, etc., are coordinated to produce comfortable vision and easy

and rapid reading with comprehension. In other words, legibility deals with the coordination of those typographical factors inherent in letters and other symbols, words, and connected textual material which affect ease and speed of reading.[42]

Scotch Roman

3. This morning my mother asked me to find out what time it was. I therefore ran just as rapidly as

Garamond

3. This morning my mother asked me to find out what time it was. I therefore ran just as rapidly as I

Antique

3. This morning my mother asked me to find out what time it was. I therefore ran just as

Bodoni

3. This morning my mother asked me to find out what time it was. I therefore ran just as rapidly as

Old Style

3. This morning my mother asked me to find out what time it was. I therefore ran just as

Caslon

3. This morning my mother asked me to find out what time it was. I therefore ran just as rapidly as

Kabel Light

3. This morning my mother asked me to find out what time it was. I therefore ran just as rapidly as I could to

Cheltenham

3. This morning my mother asked me to find out what time it was. I therefore ran just as rap-

American Typewriter

3. This morning my mother asked me to find out what time it was. I therefore

Cloister Black

3. This morning my mother asked me to find out what time it was. I therefore ran just as rapidly as

FIG. 4.1—Styles of type face.[43]

Of the ten type faces shown on the preceding page, the following listing shows the opinions on relative legibility from Tinker's test group of readers.

Type Face	Average Rank	Rank Order[44]
Cheltenham	2.3	1
Antique	2.4	2
Bodoni	4.2	3
Old Style	4.6	4
Garamond	5.4	5
American Typewriter	5.5	6
Scotch Roman	6.2	7
Caslon Old Style	6.4	8
Kabel Light	8.2	9
Cloister Black	9.8	10

As determined by type comparisons for legibility, visibility, perceptibility, and speed of reading, "speed of reading appears to provide the most valid determination of legibility of type faces," since this measurement is indicative of an ordinary reading situation.[45] (Legibility being that type which can be read easily and rapidly.) The following table indicates the speed of reading of different type faces using Scotch Roman as a standard.

Type Face	Differences in Percent[46]
Scotch Roman (standard)	0.0
Garamond	+ 0.4
Antique	- 0.2
Bodoni	- 1.0
Old Style	- 1.1
Caslon Old Style	- 1.3
Kabel Light	- 2.2
Cheltenham	- 2.4
American Typewriter	- 4.7
Cloister Black	-13.6

Where reader preference and degree of legibility are close in rank, choosing the type according to reader preference would seem to be

advantageous for publishers of reading materials of all kinds.

It has been determined that Italic print is read more slowly than ordinary lower case print, and that the majority of readers do not care for reading Italic print. Thus, it should be used only for emphasis.

Research has also shown that lower case print is more easily read than all capitals. Examination of lower case and capitals reveals that the shape of a word, as in lower case type, aids in recognition.

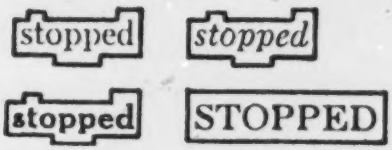


FIG. 4.2—Block outlines of the printed word "stopped" illustrate that lower case, italics, and boldface exhibit a characteristic "word form," whereas "word form" is absent when printed in all capitals.[47]

All capital print reduces speed of reading and is judged by readers to be less legible. Boldface type is read at the same rate as ordinary lower case print. Material using a mixture of type forms retards the speed of reading and the ordinary lower case type is preferred when compared to the mixed type forms.

Another illustration demonstrates that the shapes of the upper half of letters "furnishes more clues to 'word form' than the lower half."

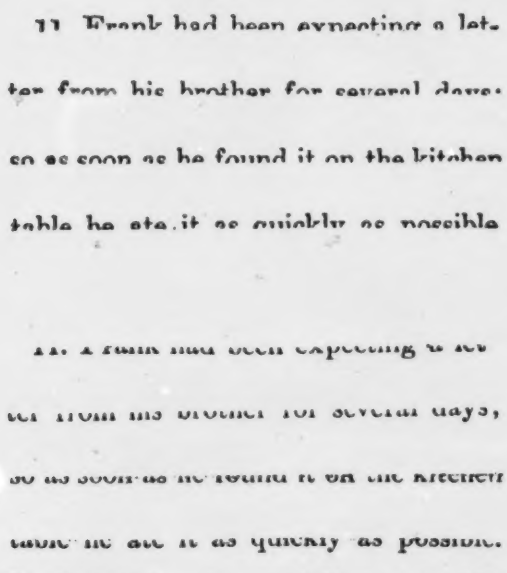


FIG. 4.3—This illustrates how the upper half of a printed line furnishes more clues to "word form" than the lower half.[48]

Readers, when asked to judge the legibility of type sizes chose 11-point type first, followed by 10 and 12 point (evenly ranked), 9 point, and 8 point.

Other factors taken into consideration with size of type are "line width," which refers to the line length across the page, and the "leading," the separation of lines of type in printing. Line width is measured in "picas," a pica being about one-sixth inch. Readers prefer moderate line widths as opposed to long or very short line widths.

Most 10-point type is set with 2-point leading, and, in a few instances, 12 point was set with larger amounts of leading. Evidently editors believe that leading improves legibility of type. Studies show that for 10-point type in a 19-pica line width, 2-point leading is

apparently optimal. When optimal line widths and leading are used, 11 point was judged most legible by readers, an opinion confirmed by measured legibility.

6 point

16. This band of men and women set sail for the new world where they could live in peace. There was great rejoicing when

8 point

16. This band of men and women set sail for the new world where they could live in peace. There was great rejoicing when

9 point

16. This band of men and women set sail for the new world where they could live in peace. There was great rejoicing when

10 point

16. This band of men and women set sail for the new world where they could live in peace. There was

11 point

16. This band of men and women set sail for the new world where they could live in peace. There was

12 point

16. This band of men and women set sail for the new world where they could live in peace.

14 point

16. This band of men and women set sail for the new world where they

FIG. 5.1—Seven sizes of type set solid, 19-pica line width. Six through 12 point are Granjon, 14 point is Scotch Roman. 49

9 picas.

6. Mr. Smith gave a news-
boy a quarter for a paper

13 picas

6. Mr. Smith gave a newsboy a quar-
ter for a paper and left without his

17 picas

6. Mr. Smith gave a newsboy a quarter for a paper
and left without his change. When the boy ran and

21 picas

6. Mr. Smith gave a newsboy a quarter for a paper and left
without his change. When the boy ran and told him he said he

25 picas

6. Mr. Smith gave a newsboy a quarter for a paper and left without
his change. When the boy ran and told him he said he had never

29 picas

6. Mr. Smith gave a newsboy a quarter for a paper and left without his change. When
the boy ran and told him he said he had never seen such dishonesty. 7. It was a cold day

33 picas

6. Mr. Smith gave a newsboy a quarter for a paper and left without his change. When the boy
ran and told him he said he had never seen such dishonesty. 7. It was a cold day in winter and the

37 picas

6. Mr. Smith gave a newsboy a quarter for a paper and left without his change. When the boy ran and
told him he said he had never seen such dishonesty. 7. It was a cold day in winter and the ground was cov-

FIG. 6.1—Line widths for 8-point type, Scotch Roman, set solid. 50

Rule with no space between columns

1. Mary was sitting on the seashore one hot day in June. She said to her mother, "If only I had | 16. This band of men and women set sail for the new world where they could live in peace. There

½ pica on each side of rule

1. Mary was sitting on the seashore one hot day in June. She said to her mother, "If only I had | 16. This band of men and women set sail for the new world where they could live in peace. There

½ pica on each side of rule

1. Mary was sitting on the seashore one hot day in June. She said to her mother, "If only I had | 16. This band of men and women set sail for the new world where they could live in peace. There

½ pica space between columns

1. Mary was sitting on the seashore one hot day in June. She said to her mother, "If only I had | 16. This band of men and women set sail for the new world where they could live in peace. There

1 pica space between columns

1. Mary was sitting on the seashore one hot day in June. She said to her mother, "If only I had | 16. This band of men and women set sail for the new world where they could live in peace. There

2 pica space between columns

1. Mary was sitting on the seashore one hot day in June. She said to her mother, "If only I had | 16. This band of men and women set sail for the new world where they could live in peace. There

FIG. 8.2—Space and rules between columns, Scotch Roman, 10 point, 19 picas, 2-point leading. 51

Another factor in legibility is the color of the print and the paper, and the quality and surface of the paper, matte to glossy. Although white print on black paper is striking and useful in some cases, for ordinary reading, black print on white paper was preferred by 77.7 percent of the readers, and test results show black on white is 10.5 percent faster to read. Black print on tinted paper varies in visibility but so slightly that legibility in the usual reading task would not be affected.

With colored pens in common usage, a comparison of colored inks on white and tinted papers is significant. The most legible combinations have been found to be dark inks on light-colored papers. Dark ink on dark-colored paper is to be avoided. Black ink on white paper is the most legible, but green on white, blue on white, and black on yellow retard reading very slightly. Green and blue inks on white paper are considered nearly as effective as black on white. Use of red on yellow is not recommended where speed of reading is important. Red on white and green on red are quite illegible. Orange on black, orange on white, red on green, and black on purple should almost never be used.

> The use of light tints of paper for printing appears to have merit. Visibility of print and speed of reading for print on light tints (cream, ivory, pale green, pink, etc.) is as good as on ordinary grades of white book paper when 10- to 12-point type is used. Dark-colored inks coordinated with colored tints of paper can be as legible as black print on white paper provided (a) the reflectance of the paper is 70 percent or greater, (b) the colored ink has a reflectance low enough so that the brightness contrast between print and paper is about 65 percent (i.e., 1 to 8 ratio), and (c) the size of type is 10 point or larger. There is a trend in printing for use in ordinary reading situations which incorporates these requirements. It is likely that many readers will prefer such an arrangement on esthetic grounds.[52]

The following are suggestions for educators to ease the reading tasks of students and teachers in the classroom:

(1) Since pencil and ball-point pen are more glossy than ink writing, the use of low-gloss ink should be encouraged.

(2) The minimum type size to be used in textbooks is considered to be 10-point Bodoni. Younger pupils should use a larger type size to make reading tasks easier. Also important are adequate spacing between lines of type and the use of low-gloss ink.

(3) For both working paper and printed material, matte paper should be used in preference to glossy.

(4) Paper should have a good degree of opaqueness and a high reflectance.

(5) The proper combination of chalk, chalkboard and illumination should be provided. Supplementary lighting is required for chalkboards, for light boards to compensate for reduced contrast and for dark boards to attain acceptable brightness. White chalk has been found more visible than other light-colored chalks, such as yellow. Only a high grade of chalk, with a minimum of clay filler, should be used. Chalkboards should be kept clean and periodically restored to good condition. Teachers should be encouraged to use large letters and figures.

(6) Of special importance is the quality of duplicated material. Since poor duplicated copies have been shown to require the highest illumination levels, it would be worthwhile to consider the cost of quality duplication machinery and skilled operation against cost of increased illumination requirements.

(7) In general, the visibility of tasks may be improved not only by additional illumination, but also by providing tasks having the maximum contrast and the minimum specularity within the task. Often this may be done at a minimum of expense. All that is needed is an understanding of what constitutes a good task and a desire to provide one to the greatest degree possible.[53]

The Teacher's Responsibility

Once the designer and contractor have completed a teaching space,

then the teacher must be cognizant of the lighting and her part in the control of lighting and the visual tasks. The teacher selects the teaching materials, supervises seating arrangements, plans the schedule, etc. The use of dark red and dark blue notebook paper for assignments builds eye strain and physical stress into the visual tasks—for both students who do the written work and the teacher who must read their papers. The contrast of pencil against these dark colors is insufficient and difficult to read. Use of teaching material with high gloss paper or poor contrast between print and paper, poorly duplicated material, poor contrast of chalk and chalkboard--all cause visual fatigue, accompanying physical fatigue, and muscular and skeletal stress.

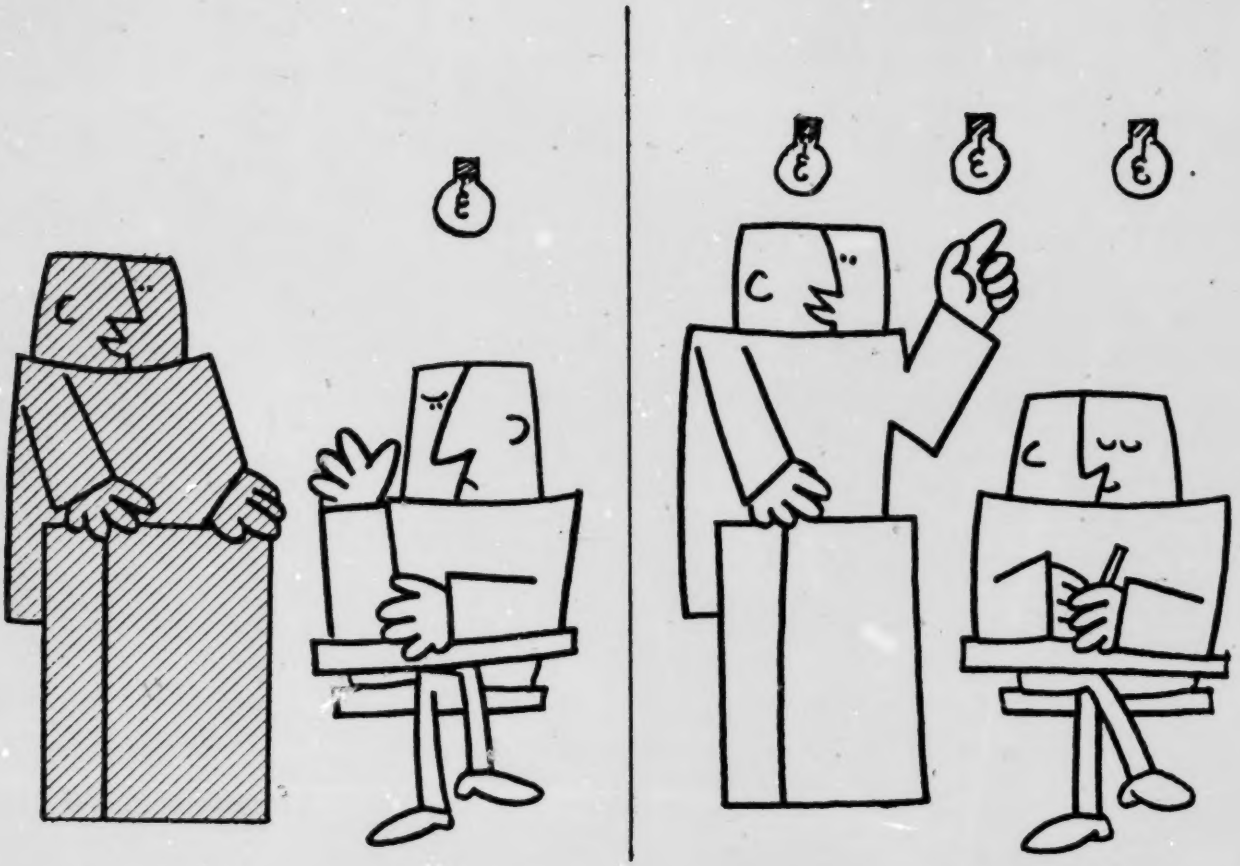
When writing material on the chalkboard, the teacher must consider that some students may be twenty feet or more away, therefore, adequate letter size is important. The size of the print in textbooks and on duplicated material should also be a consideration, especially in the primary grades, along with adequate spacing between lines of type. The use of matte paper with substantial opaqueness and high reflectance is advisable. Materials such as maps and charts which have become soiled, faded, and difficult to read should be discarded. It is best to avoid making displays between windows where light contrast makes for strained reading conditions. Adjusting the shades helps to prevent glare.

Glare on the TV screen should be eliminated. An efficient method of avoiding this is through the use of a hood over the screen which will cut glare and reflections and improve the picture contrast.

The set should be placed so the students are not facing the windows, and the room should not be completely darkened. Rheostats on the light switches are convenient in adjusting light levels for TV and other media.

Seating arrangements should take into consideration the children with hearing problems who will benefit from particularly good lighting,[54] and any students with "retinal degenerative disease," low vision from high degrees of myopia, optic nerve atrophy, and certain other special conditions; and it should be considered who will benefit from sitting on the window side of the room.[55] On the other hand, children with albinism, nuclear cataracts, and certain iris conditions may function better on the darker side of the room.[56] Of course, any student's physician should be consulted about such problems. Twenty percent of the children in school have below normal vision.[57] Allowing students to change seats whenever this will provide better conditions for visual work, and making sure no students face a light source such as a window, or works in his own shadow, is also beneficial.

The lighting should remain fairly constant during visual tasks. Eye strain occurs with extremes as when slide changers direct a brilliant beam of white light followed by darkness and then the picture, or with the use of the overhead projector. Another extreme adjustment occurs when students come in from sunlit playgrounds where the foot-candles may measure over 2000, and are given an assignment requiring the reading of fine print, or are shown a movie. The major light adjustment occurs within a few minutes; however, eye adjustment may continue in some children for ten minutes or more.[58]



HEARING ACUITY IS INCREASED WHEN THE LEVEL OF ILLUMINATION IS INCREASED IN THE ENTIRE ROOM.

(Illustration from Environment for Learning)

These considerations combined with the alternation of close eye work tasks with activities requiring fewer visual demands, will contribute to the prevention of visual, mental, and physical fatigue.

Adhering to all recommended lighting principles may still leave a classroom devoid of atmosphere. Atmosphere is an emotional reaction to a space which cannot be defined in foot-candles or reflection factors. In designing the lighting of a school, economics may need tempering for additional elements such as courtyards, supplementary lighting, and adequate switching.

> . . . whatever the view, experimental psychologists have shown that the human organism prefers complexity and ambiguity in its visual field. Relating this to "information theory," we might say that man needs information in order to keep his brain interested in the task at hand. Unless the visual field can offer this complexity, and offer it at a rate that is manageable yet challenging, the viewer is going to lose interest. It makes little difference if this informational display is a set of slides, a bulletin board, or a piece of architecture; unless it presents information and enough complexity for his perceptual field, the human organism will not enjoy his environment.[59]

Providing the "information and complexity" is accomplished only through the combined efforts of the architect, the interior designer, and the teacher.

NOTES

1. Educational Facilities Laboratory, SER 2 Environmental Evaluations. (University of Michigan: Architectural Research Laboratory, Department of Architecture, 1965), p. 24.

2. Ibid., p. 125.

3. McVey, G. F. Environment for Learning. (U. S. A.: G. F. McVey, 1969), p. 25.

4. Ibid., p. 23.

5. "Classroom Lighting," (National Society for the Prevention of Blindness, 1963), p. 4. (ED 019 822)

6. Handler, Benjamin. Economic Planning for Better Schools. (Ann Arbor: University of Michigan, College of Architecture and Design, 1960), p. 39.

7. Levy, Charles and Howe, William. "Brighten Your Corner." (Broadcast No. 7464, California University, Los Angeles: University Explorer, January, 1967), p. 3. (ED 019 821)

8. "Classroom Lighting," p. 3.

9. Ott, John N. Health and Light. (New York: Pocket Books, 1976), p. 116.

10. Crouch, C. L. "Vision Is Paramount--but it isn't the only thing." American School and University, (August, 1974), p. 35.

11. Ott, John N. Health and Light, p. 192.

12. Maas, James B., Jayson, Jill K. and Kleiber, Douglas A. "New Developments in Lighting." American School and University, (August, 1974), p. 31.

13. Falk, Norman. "New Standards for Classroom Lighting." American School and University, (March, 1972), p. 21.

14. "Classroom Lighting," p. 3.

15. Falk, Norman. "New Standards for Classroom Lighting," p. 24.

16. Alexander, Mary Jean. Designing Interior Environment. (New York: Harcourt Brace Jovanovich, Inc., 1972), p. 93.

17. Ibid., p. 94

18. Ibid., p. 94.

19. Falk, Norman. "New Standards for Classroom Lighting," p. 24.

20. Ibid., p. 26.

21. "Old Axioms Give Way to New Advances." American School and University, (August, 1974), p. 34.

22. Falk, Norman. "New Standards for Classroom Lighting," p. 24.

23. "Old Axioms Give Way to New Advances," p. 35.

24. "Classroom Lighting," p. 9.

25. Ott, John N. Health and Light.

26. Stein, Carl (AIA). "School Lighting Re-evaluated." American School and University, (October, 1975), p. 72.

27. Ibid., p. 72.

28. Educational Facilities Laboratory, SER 2 Environmental Evaluations, p. 118.

29. Gwynne, Susan K., ed. Guide for Planning Educational Facilities. (Columbus, Ohio: Council of Educational Facility Planners, International, 1976), p. I-4.

30. Ibid., p. I-5.

31. Educational Facilities Laboratory, SER 2 Environmental Evaluations, p. 120.

32. Falk, Norman. "New Standards for Classroom Lighting," p. 24.

33. Levy, Charles and Howe, William. "Brighten Your Corner," p. 3.

34. Falk, Norman. "New Standards for Classroom Lighting," p. 24.

35. "How Much Lighting Is Enough?" Nation's Schools, (January, 1970), p. 86.

36. Sampson, Foster K. Contrast Rendition in School Lighting. (New York: Educational Facilities Laboratory, Inc., 1970).

37. "How Much Lighting Is Enough?", p. 87.

38. Corgan, C. Jack. "Overhead Planning for Open-Plan Schools," p. 48.

39. Stein, Carl (AIA). "School Lighting Re-evaluated." American School and University, (October, 1975), p. 77.

40. Falk, Norman. "New Standards for Classroom Lighting," p. 28.

41. SER 2 Environmental Evaluations, p. 125.

42. Tinker, Miles Albert. Legibility of Print. (Ames: Iowa State University Press, 1963), pp. 7-8.

43. Ibid., p. 47.

44. Ibid., p. 49.

45. Ibid., p. 54.

46. Ibid., p. 48.

47. Ibid., p. 60.

48. Ibid., p. 61.

49. Ibid., p. 70.

50. Ibid., p. 75.

51. Ibid., p. 119.

52. Ibid., pp. 150-151.

53. Educational Facilities Laboratory, SER 2 Environmental Evaluations, p. 126.

54. McVey, G. F. Environment for Learning, p. 8.

55. Wilson, Charles C., M.D., ed. Healthful School Living. (Washington, D. C.: National Education Association, 1957), p. 166.

56. Ibid., p. 166.

57. "Classroom Lighting," p. 5.

58. McVey, G. F. Environment for Learning, p. 23.

59. Ibid., p. 13.

SELECTED BIBLIOGRAPHY

Books

Alexander, Mary Jean. Designing Interior Environment. New York: Harcourt Brace Jovanovich, Inc., 1972.

Birren, Faber. Color for Interiors--Historic and Modern. New York: Whitney Library of Design, 1963.

David, Thomas G. and Wright, Benjamin D., eds. Learning Environments. Chicago: The University of Chicago Press, 1974.

Educational Facilities Laboratory. SER 2 Environmental Evaluations. University of Michigan: Architectural Research Laboratory, Department of Architecture, 1965.

Guide for Planning School Plants. Nashville, Tennessee: National Council on Schoolhouse Construction, 1953.

Gwynne, Susan K., ed. Guide for Planning Educational Facilities. Columbus, Ohio: Council of Educational Facility Planners, International, 1976.

Handler, Benjamin. Economic Planning for Better Schools. Ann Arbor: University of Michigan, College of Architecture and Design, 1960.

McVey, G. F. Environment for Learning. U. S. A.: G. F. McVey, 1969.

Ott, John N. Health and Light. New York: Pocket Books, (original publication by the Devin-Adair Company, 1973), 1976.

Sampson, Foster K. Contrast Rendition in School Lighting. New York: Educational Facilities Laboratory, Inc., 1970.

Sommer, Robert. Design Awareness. San Francisco: Rinehart Press, 1972.

Tinker, Miles Albert. Legibility of Print. Ames: Iowa State University Press, 1963.

Wilson, Charles C., M. D., ed. Healthful School Living. Washington, D. C.: National Education Association, 1957.

Magazines

"Brightness Patterns Improve Classroom Attention." American School and University, August, 1974, p. 32.

"Contrast Rendition in School Lighting." Nation's Schools, January, 1970, pp. 86-88.

Corgan, C. Jack. "Overhead Planning For Open-Plan Schools." American School and University, March, 1972, pp. 48-50.

Crouch, C. L. "Vision Is Paramount--but it isn't the only thing." American School and University, August, 1974, p. 35.

Falk, Norman. "New Standards for Classroom Lighting." American School and University, March, 1972, pp. 21-28.

"Lighting an Open Plan School." School Management, February, 1972, p. 22.

Maas, James B., Jayson, Jill K. and Kleiber, Douglas A. "New Developments in Lighting." American School and University, August, 1974, p. 31.

"Old Axioms Give Way to New Advances." American School and University, August, 1974, pp. 34-35.

Sandstrom, Harvey E. "Replacement Windows Help Reduce Fuel Bill 34%." American School and University, February, 1974, p. 58.

"Select Lighting with Energy in Mind." American School and University, March, 1974, p. 54.

Stein, Carl (AIA). "School Lighting Re-evaluated." American School and University, October, 1975, pp. 70-78.

Microfiche

"Classroom Lighting." National Society for the Prevention of Blindness, 1963. (ED 019 822)

Levy, Charles and Howe, William. "Brighten Your Corner." (Broadcast No. 7464), Los Angeles: California University, University Explorer, January, 1967. (ED 019 828)

Pena, William A. "Predetermination of Natural Illumination by the Model Testing Method." Bryan, Texas: Caudill, Rowlett, Scott and Associates, 1957 (ED 018 929)

Turek, Robert W. "Seeing Parameters--Physical Aspects of Light." Madison: Lighting Techniques in Architecture, Chicago Lighting Institute, Illinois, December, 1969. (ED 031 932)

White, Sally. "Physical Criteria for Adult Learning Environments." Washington, D. C.: Adult Education Association of U. S. A., Commission on Planning Adult Learning Systems, Facilities, and Environments, October, 1972. (ED 080 882)